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Hydro-Physicochemical Changes in Domasi River Associated with Outbreak of Blackflies (Diptera; Simuliidae) in Zomba, Malawi

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Abstract

Blackflies impact human and animal health due to their biting nuisance and transmission of Ochocerca volvulus. This study presents an attempt to analyze hydro physicochemical changes associated with outbreak of black flies in Zomba, Malawi. The study compared historical data of hydro physicochemical parameters before (1985-2002) and after (2008) the outbreak to deduce the changes associated with mass occurrence of these flies. Changes in water quality between these two periods were assessed using T-tests. To establish the relationship between the black fly larval densities and water quality parameters data was subjected to both principal component and correlation analysis. Three principal components before the outbreak and two principal components during the outbreak (both dry and wet season) accounted for most of the variation in water quality in this river system. Nutrient load, increases in Total Suspended Solids (TSS) and Total Hardness (TH) were the main factors that had high loadings on these principal components over the years. A significant correlation was established between black fly larval densities and total hardness (r=0.86, p<0.05) as well as total suspended solids (r = 0.755, p<0.02). The potential role of anthropogenic influences on water quality and its cascading effect on black fly population dynamics is discussed.

Introduction

Blackflies (Diptera: *Simuliidae*) are small bloodsucking flies of worldwide distribution, occurring in proximity of streams and rivers where their early stages develop (Bukacinski and Bukacinska, 2000). Larval black flies are filter feeders and are usually aggregated in oxiginated sections of streams, rivers and waterways (Werner and Pont, 2003). High densities of small suspended solids, high turbidity, high total phosphorous and nitrogen concentrations, low cover of filament algae on the substratum and low altitude affect their survival (Zhang *et al*., 1998). Particle concentrations are positively related to their species richness and abundance (Cummins and Klug, 1979) although this varies from species to species. Bernotiene, (2006), reported the most important factor for the larvae of S. *rostratum* as water rich in nitrates, with a mean pH of at least 8 or higher, while larvae of S. *ornatum* preferred hard clean water with low pH. Their preference for their habitats may be affected by instability of the environment and subsequently affect their population fluctuations. A growing body of literature reports Simuliids to be of economic importance in many parts of the world including Africa, because of their biting nuisance, transmission of pathogens that affect humans and even livestock. In Afro-tropical region alone, (Crosskey,1980) reported 166 known Simuliid species. In Malawi, the presence of blackflies is of age (see Adler and Crosskey,2013) yet earliest studies only indicated Thyolo District as a focus where their attendant health implications became apparent (Johnston *et al*. 1994; Roberts 1990). Subsequent studies revealed Mwanza as another focus (Courtright *et al*. 1995). Although Roberts (1988) reported the presence of black flies in Mulunguzi River, Zomba, there was no indication that these insects caused any health problem in this area at the time. Black flies of the

Simulium damnosum complex and *Simuliun neivei* were however recently reported in the same district by Pemba and Alezuyo in 2006 as a health menace. Whether physicochemical changes in the black fly larvae habitats led to the outbreak of black fly populations in this district is unknown. This study was carried out to investigate hydrophysico-chemical changes associated with the outbreak of black flies in the Domasi River system in Zomba.

Materials and Methods

Study site

Zomba district is located 150 17 South and 350 24 East with an approximate area of 2,580 square kilometers representing 3% of the total land area of Malawi (Government of Malawi (GOM), 2000), has its highest point as Zomba-Malosa Plateau, source of numerous rivers, including Domas river, one of the main focusof the recent blackfly population explosion. This site was chosen for this study. Investigations started from July 2008 to December 2008 in Domasi River, Zomba-Malosa plateau,in which *Simulium damnosum* was the predominant species. The upper and the middle sections of the river are in the forest reserve. The lower stream is characterized by reeds. Major human activities related to this river system undertaken by local inhabitants include subsistence farming close to the river banks as well as bathing and washing.

Collection of water samples

Small water sampling sections were selected at systematically distributed points over the entire length of the river. Electrical conductivity (EC), temperature and dissolved oxygen (DO) were measured in the field immediately after the collection of samples using EC meter and DO meter (Cole Palmer, model 5946-75). Hydrogen ion concentration (pH) was measured soon after in the laboratory on the same day of sampling using a pH meter (Metrohm 827 pH lab). Ion Chromatography (IC) was used to test the concentration of nitrates and free phosphates. Testing for Total suspended solids (TSS), Alkalinity and Total Hardness (TH) was done in the laboratory following standard methods as outlined in AOAC (1990). Historical physicochemical data (1985-2002) before the outbreak was collected from Central Water Laboratory in Lilongwe.

Larval density data

Larval density was estimated using a scale developed by Palmer (1997) from the substrates at the same points in the river where water was sampled.

Data Analysis

Principal component analysis (PCA) was used to identify the likely principal factors that caused variations in physicochemical compositions. To establish changes in the physicochemical constituents over the years, Student's t-test was carried. This was done on assumption that there was no difference in means of the variables which were being tested (Clarke and Cooke, 1998). Hydro-physicochemical parameters in the periods 1985-2002 and 2008 were further tested for associations with larval densities. Regression analysis of the principal components was used to deduce the associations between the larva densities and the test parameters.

Results

Temporal changes in physicochemical properties of water in Domasi River

Total hardness was higher during than before the black fly outbreak period (p=5.137E-06). A similar pattern was observed for alkalinity (p=0.001), nitrates (p=0.001) and total suspended solids (p=0.011). The amount of phosphates was lower in the fly break out period (p=0.030) relative to the time before it. No differences were observed in the levels of electrical conductivity (p=0.314) and pH between the two periods (p=0.600). In the fly break out period, seasonal variations in the water quality parameters were observed. An increase in total suspended solids (TSS) (p=6.000E-04), total hardness (p=2.140E-19), total alkalinity, (p=1.560E-05) was observed in the wet season. Dissolved oxygen (DO) however decreased in the same season (p=1.00E-04). The outline of seasonal and temporal variations in these physicochemical constituents is shown in figure 1.

Principal Component Analysis

Principal component analysis was conducted to reduce the dimensionality of this multivariate data set to facilitate further analysis of key water quality factors or patterns in Domasi River. Principal components were selected using Kaiser Normalization to identify the variables that accounted for most of the total variance in water quality in the years before and after the black fly outbreak. Detailed explanation of principal component analysis may be found in (Jordan1995; Jayaprakash, 2007). Results of the principal component analysis are shown in Table 1. The first three principal components (PC1, PC2, PC3) together accounted for 89.91% of the total variance in water quality (PC1 = 50.67%, PC2 = 23.00%, PC3 = 16.24%) in the pre-black fly break out period. The levels of pH, electrical conductivity and alkalinity had high positive loadings (0.69-0.97) on PC1 while total hardness and phosphates showed high positive loadings (0.86 - 0.94) on PC2. Total suspended solids had a high loading (0.95) on PC3.

In the wet season of the black fly break out period, two PCs accounted for 70.37% of the variance in water quality; PC1 contributed 44.32% while PC2 accounted for 26.04%. Electrical conductivity, total hardness, nitrates and alkalinity had high positive loadings on PC1 (0.72-0.98) while dissolved oxygen concentration showed moderate positive loadings on PC2 (0.59). In the dry season of the black fly break out period, two PCs also accounted for a similar amount of variance (70.15%) in water quality; dissolved oxygen, electrical conductivity and nitrates had high positive loadings (0.76-0.82) on PC1 which accounted for 46.24% of variance in water quality while pH had high positive loadings (0.75) on PC2 which accounted for 23.91% of the total variance in water quality.

Correlation patterns of the physicochemical parameters and the blackfly larvae

To test for the potential association between the densities of black fly larvae with the hydro-physicochemical parameters measured, data from the black fly out break period only was subjected to correlation analysis. Results of this analysis are presented in Tables 2 and 3. Black fly larvae densities showed substantial positive relationships with electrical conductivity (R=0.815, p=0.024), total hardness (R=0.859, p=0.014) in the dry season. Similar results were observed during the wet season where larvae densities positively correlated with levels of phosphates (R=0.813, p=0.024) and total suspended solids (R=0.76 p=0.041). However there was a strong negative relationship between larvae black flies and dissolved oxygen (R=-0.732 p=0.049).

Discussion

Results show that the physicochemical constituents of the water in Domasi River have changed over the years and were different between the periods, namely before and during the black fly outbreak. More importantly, this study uncovers significant correlations between water quality and black fly larvae densities during the outbreak, potentially pointing to the important influence of variations in habitat quality to black fly densities. Successful colonization of the larvae *Simuliids* depends on the suitability of the microhabitats (Roberts,1988). In this study, black fly larvae densities were positively related with electrical conductivity as well as levels of phosphates and total suspended solids but were negatively related with dissolved oxygen concentration. Electrical conductivity and dissolved oxygen had high loading on the PCs that accounted for most of the variation in water quality during this period.

The association of black fly larvae with the total suspended solids found in this study is an important result that resonates well with other studies that have detected increases in black fly densities after flood-induced increases in total suspended solids (Vora 2008). Black flies feed non-selectively on organic matter (Zhang *et al*. 1998). Suspended particles may have as much as 95% organic content (Palmer, 1997) and are thus crucial to black fly larvae because of their high nutritional quality (Zhang *et al*. 1998). The upsurge of the black flies could therefore be attributed to increased suspended solids that offer a valuable trophic resource for the suspension feeding black flies.

These findings also demonstrate significant correlations between larva density and total hardness (non-carbonate type), a measure of the amount of calcium and magnesium ions in the water which has a positive compositional relationship with nutrients like sulphates and nitrates (Tebbutt, 1998). Nitrates are nutriens essential for survival of living things.The study demonstrates that black fly larvae prefer river microhabitat sites that have high nutrient load. Anthropogenic influences, including but not limited to use of fertilizers and changes in the land use system may contribute to the loading of nutrients from catchments to river systems (Bhardwaj *et al*,.2010). This study has revealed an increase in total hardness concentration over the years. This might have had a cumulative influence on the black fly larvae density in the period preceding the fly outbreak. The study detected a decrease in phosphate concentration in the river over the years. The availability of the phosphates in natural waters is dependent on several factors and these including co-precipitation and adsorption as well as uptake by biota, the use of phosphates by aquatic vegetation as well as increase in the metal oxides reduce the availability of phosphate ions in water (Hem 1991). The study could not establish which of these factors was at play..

The increased alkalinity in the river system was associated with the wet season. In natural waters, alkalinity is due to dissolved carbon dioxide, bicarbonate and carbonate (Tebutt, 1998). Although the principal source of carbon dioxide that feeds into the alkalinity of surface waters is the CO2 gas in the atmosphere, substantial amounts of this gas also come from soils that span the unsaturated zone between the land surface and the water table (Hem, 1991). Decayed dead plant material contributes significantly to this soil CO2 which finds its way to various water bodies through soil runoff (Hem,1991). This may explain why increased alkalinity in Domasi River coincides with the wet season when runoff water swells its volume substantially.

The study lacked larvae density data before the outbreak and this hampered the efforts to produce substantial extrapolations about the interaction between long term changes in water quality and black fly populations in this river system. This study proposes continuous ecological monitoring studies of blackfly populations willinclude detailed investigations of microclimates and considers such variables like air temperature and degree-days. This may facilitate the predictive modeling of further mass occurrence of these black flies and thus safeguard public health.

Reference

Adler, P. H., & Crosskey, R. W. (2013). World Blackflies (Diptera : Simuliidae): A Comprehensive Revision Of The Taxonomic And Geographical Inventory [2013] World Blackflies (Diptera : Simuliidae): A Comprehensive Revision Of The Taxonomic And Geographical Inventory [2013].

Association of Official Analytical Chemists (1990). Official Methods of Analysis 15th Ed,Associaton of Official Analytical Chemists(AOAC), Virginia. USA.

Bhardwaj, V., Singh, D. Sen, & Singh, A. K. (2010). Water quality of the Chhoti Gandak River using principal component analysis , Ganga Plain , India, (1), 117–127.

Bukaciski,D and Bukacinska, M. (2000). The impact of mass outbreaks of blackflies (Simuliidae) on the parental behavior and breeding output of colonial common gulls (larus Canus). Annales Zoologici Fennici 37: 43-49. Finnish Zoological and Botanical Publishing Board.

Bernotienė, R. (2006). The Distribution of Black Fly Larvae In Small Low Land Rivers Lithuania. Lithuania: Institute of ecology of Vulnius University.

Courtright, P., K. Johnston and L. Chitsulo, (1995) A New Focus of Onchocerciasis in Mwanza District, Malawi. Transactions of the Royal Society of Tropical Medicine and Hygiene 89: 34-36.

Crosskey, R. W. (1980). Catalogue of the Diptera of the Afrotropical Region. London: British Museum (Natural history) pp1437.

Cummins, K.W and Klug, M.J. (1979). Feeding Ecology of Stream Invertebrates. Animal Review of Ecology and Systematics. 10:147-172.

Clarke, G.M and Cooke, D. (1998). A Basic Course in Statistics. New York: Oxford University Press (4th Edition).

Government of Malawi (GOM) (2000). Zomba District Socio-Economic Profile. Zomba: Government print.

Hem, J .D. (1991). Study and Interpretation of the Chemical Characteristics of Natural Water. U.S. Geological Survey water–supply paper 225. Jodhpur: Scientific Publishers.

Jayaprakash, M., Giriharan, L., Venugopal, T., Krishna kumar,S.P and Periakali P.(2007).Characterization and Evaluation of the Factors Affecting the Geochemistry Of Groundwater in Neyveli, Tamil Nadu, India. Springer

Johnston, K., P. Courtright and G. Burnham, (1994) Knowledge and Attitudes toward Onchocerciasis in The Thyolo Highlands Of Malawi. Tropical Medicine and Parasitology 45: 341-343.

Jordan, R.,Bachman ,J. L., Ferrari M.J. (1995). Quality and Geochemistry of Groundwater In Southern New Castle County, Delaware. Report of Investigations Number 52. U.S.A. Geological Survey.

Palmer, R.W. (1997) Principles of Integrated Control of Blackflies (Diptera: Simuliidae) in South Africa. Water research commission Report No 650/1/97.

Pemba, D.F and Alezuyo .C.,(2006). Zomba Blackfly Outbreak Report to the Ministry of Health. Zomba: Biology Department, Chancellor College.

Roberts, M. J., 1990 Vectors Of Onchocerciasis In The Thyolo Highlands And Other Onchocerciasis Foci In Malawi. Acta Leidensia 59: 45-48.

Roberts, T. M. T. (1988). Biology of Simuliid Larvae of the Mulungusi Basin, Zomba Plateau: Taxonomy and Ecological Notes. MSc. Thesis, University of Malawi, Chancellor College; Zomba.

Tebbutt, T.H.Y. (1998). Principles of Water Quality Control. 5th Edition. Butterworth Hienemann.

Vora, N. (2008). Impact of Anthropogenic Environmental Alterations on Vector Borne Diseases. Medscape Journal of Medicine 10:238. Published online, Medscape.

Vora, N., 2008 Impact of anthropogenic environmental alterations on vector-borne diseases. Medscape journal of medicine 10: 238-238.

Werner, D and Pont, A.C (2003). Dipteran predators of Simuliid blackflies : a worldwide review. Medical and Veterinary Entomology, 115–132.

Zhang, Y. X., B. Malmqvist and G. Englund, (1998). Ecological processes affecting community structure of blackfly larvae in regulated and unregulated rivers: a regional study. Journal of Applied Ecology 35: 673-686.

Tables And Figures

Table 1. Principal components showing the hydro-physicochemical parameters of Domasi river. Factors with Eigen values greater than 1only were used. Only Factor loadings greater than 0.5, are show and were used.

Parameter	**(1985-2002) Before outbreak**			**Dry season(2008)**		**Wet season (2008)**	
Factor	**1**	**2**	**3**	**1**	**2**	**1**	**2**
Temperature				0.900		0.887	
pH	0.970				0.749		-0.725
DO				0.823			0.585
EC	0.925			0.937		0.976	
Total hardness		0.904				0.884	
Nitrates	-0.795			0.766		0.719	
Phosphates		0.860			-0.863		
Alkalinity	0.686					0.801	
TSS			0.945				-0.933
Eigen values	3.547	1.610	1.137	3.280	1.620	4.160	2.160
Variance (%)	50.667	23.004	16.236	46.240	23.910	44.320	26.040
Cumulative (%)	50.667	73.672	89.908	46.240	70.150	44.320	70.370

Table 2: A correlation matrix showing the physicochemical parameters association with the larval Simuliids in September 2008. *R* is the correlation coefficient and *P* the probability associated with the contribution of the physicochemical parameters to the larval densities

		Temp	**pH**	**DO**	**EC**	**TH**	**Nitrat**	**Phosph**	**Larva**
Correlation Coefficient (r)	pH	-.373	—						
	DO	.821	-.570	—					
	EC	.749	-.646	.586	—				
	TH	.652	-.085	.488	.738	—			
	Nitrat	.488	-.518	.220	.917	.623	—		
	Phosphat	-.046	-.372	.336	.003	-.234	-.081	—	
	Larva	.819	-.413	.709	.815*	.859*	.593	-.296	—
P-Values		Temp	—						
	pH	.233	—						
	DO	.023	.119	—					
	EC	.043	.083	.111	—				
	TH	.080	.436	.163	.047	—			
	Nitrat	.163	.146	.337	.005	.093	—		
	Phosphat	.466	.234	.258	.497	.328	.440	—	
	Larva	.466	.208	.057	.024**	.014**	.107	.284	—

Table 3 A correlation matrix showing the physicochemical parameters association with the larval *Simuliids* in December 2008. R is the correlation coefficient and P the probability associated with the contribution of the physicochemical parameters to the larval densities

			DO	**Temp**	**EC**	**Alka**	**TH**	**TSS**	**Nitrat**	**Phosph**	**larva**
Correlation											
Coefficient											
(r)	pH	—									
	DO	.429	—								
	Temp	-.977	-.416	—							
	EC	-.988	-.345	.985	—						
	Alkalini	-.625	-.323	.655	.659	—					
	TH	-.900	-.506	.925	.894	.365	—				
	TSS	-.588	-.368	-.656	-.680	-.293	-.585	—			
	Nitrate	-.937	-.312	.925	.935	.425	.950	-.717	—		
	Phosph	.915	-.718	-.268	-.268	-.073	-.141	.837	-.379	—	
	Larva	.273	-.732*	-.245	-.245	-.193	-.058	.755*	-.281	.813*	—
P-Values		pH	—								
	DO	.198	—								
	Temp	.000	.206	—							
	EC	.000	.251	.000	—						
	Alkalin	.092	.266	.079	.077	—					
	TH	.007	.153	.004	.008	.239	—				
	TSS	.110	.236	.079	.068	.286	.111	—			
	Nitrate	.003	.273	.001	.003	.201	.002	.054	—		
	Phospha	.356	.054	.304	.295	.446	.395	.019	.229	—	
	Larva	.300	.049**	.320	.246	.357	.456	.041**	.295	.024**	—